Pre-evaluation for Heat Balance of Prototype Sodium-Cooled Fast Reactor

Ji-Woong Han, Dehee Kim, Jung Yoon, Eui-Kwang Kim and Tae-Ho Lee
Korea Atomic Energy Research Institute, #150, DeokjinDong, YuseongGu, Daejeon, Republic of Korea, 305-353
jwhan@kaeri.re.kr

1. Introduction

Under the long-term advanced SFR R&D plan, the design of prototype reactor has been carried out toward the construction of the prototype SFR plant by 2028. The R&D efforts in fluid system design will be focused on developing a prototype design of primary heat transport system(PHTS), intermediate heat transport system (IHTS), decay heat removal system(DHRS), steam generation system(SGS), and related auxiliary system design for a prototype reactor as shown in Fig. 1.

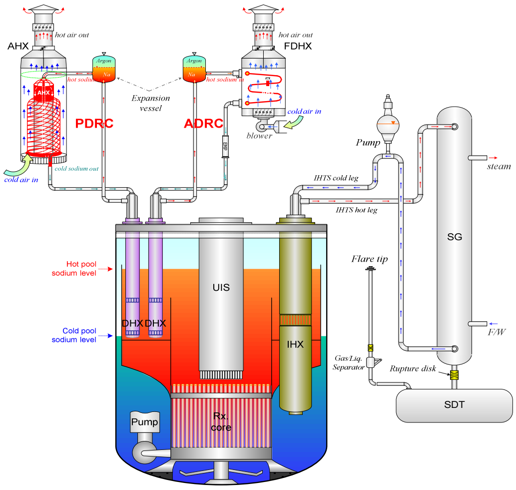

Fig. 1 Schematics of SFR system

In order to make progress system design, top-tier requirements for prototype reactor related to design parameters of NSSS and BOP should be decided at first. The top-tier requirement includes general design basis, capacity and characteristics of reactor, various requirements related to safety, performance, securities, economics, site, and etc.. Extensive discussion has been done within Korea Atomic Energy Research Institute(KAERI) for the decision of top-tier requirements of the prototype reactor.

The core outlet temperature, which should be described as top-tier requirements, is one of the critical parameter for system design. The higher core exit temperature could contribute to increase the plant efficiency. However, it could also contribute to decrease the design margin for structure and safety[1]. Therefore various operating strategies based on different core outlet temperatures should be examined and evaluated.

For the prototype reactor two core outlet temperatures are taken into accounted. The lower temperature is for the operation condition and the higher temperature is for the system design and licensing process of the prototype reactor.

In order to evaluate the operability of prototype reactor designed based on higher temperature, the heat balance calculations have been performed at different core outlet temperature conditions. The electrical power of prototype reactor was assumed to be 100MWe and reference operating conditions were decided based on existing available data. The acceptability of TBN system was not taken into accounted in this calculation. The heat balance plots at the respective core temperature conditions were compared and the plant operation strategy was examined.

2. Methods and Results

DENOP-K(DEtermination of Normal OPerating conditions of Kalimer[2]) code was utilized to evaluate the system heat balance for the virtual prototype reactor.

2.1Reference operating condition

Most of input values for DENOP-K code at reference condition were decided based on 600MWe demonstration reactor[3] and existing available data. The related description and final heat balance diagram for reference condition is presented in this section.

The BOP design values of a reference condition for prototype reactor are postulated to be the same as those of S-Prism[4]. The cited temperature and pressure for TBN(TurBiNe) stop valve is 468℃ and 17.3MPa respectively. For the feedwater temperature 215℃ is selected as an input value after the consideration of various design values for other countries' reactors employing the metal fuel[5].

Temperature differences between core inlet and outlet are selected as 155℃, which is the same as 600MWe demonstration reactor. Based on the prescribed design value the temperature deployment for IHTS is evaluated. For the decision of IHTS temperature non-dimensional temperature range is postulated from 0.1 to 0.9 and respective temperature distribution is evaluated taking into account the followings:

- Specific heat exchanger sizing parameter (UA/Q_{core})
- Flow rate requirement for IHTS
- Thermal efficiency

Fig. 2 presents the final system heat balance diagram at reference condition for 100MWe prototype reactor.

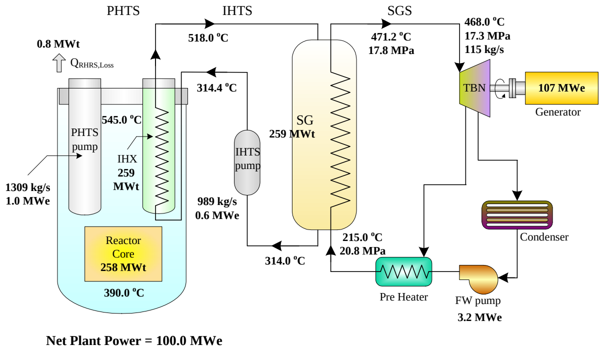

Fig. 2 Heat balance for 100MWe SFR plant at reference condition

2.2 Lowered core temperature operating condition

In order to evaluate the possibility of employing the existing major components at lowered core temperature operating condition the heat balance calculation has been performed without changing the design parameters related with heat exchangers and pumps. For this analysis the input value for BOP at reference case is employed without modifications. Temperature differences between core inlet and outlet is also preserved, however, core outlet temperature is changed from 545℃ to 510℃.

Normal operating condition based on this scenario has been evaluated by using DENOP code and is summarized in Fig. 3. As shown in figure TBN power, PHTS and IHTS pump capacity, heat transfer rates were preserved. However, temperature deployment of BOP and IHTS was changed. The steam mass supplied to SG was also changed to make up for the temperature difference reduction at TBN inlet in compared with reference case. Therefore it is necessary to employ large capacity FW pump to accept this operating condition.

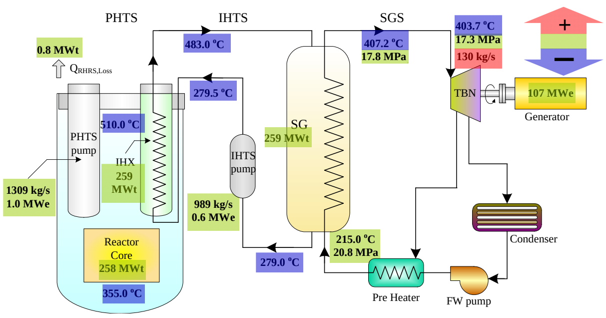

Fig. 3 Heat Balance for 100MWe SFR plant at lowered core temperature condition with nominal power operation

For the target of developing operation mode utilizing the same components of reference system at lowered core exit temperature, an additional heat balance calculation has been performed. As shown in Fig. 4. every parameter related to components such as PHTS, IHTS and FW pump capacity, heat transfer rates were preserved in comparison with reference, except TBN power and temperature deployment.

This represents that it is possible to operating the reference system at lowered core temperature condition without changing the major components under the low-power TBN operation and decreased steam temperature.

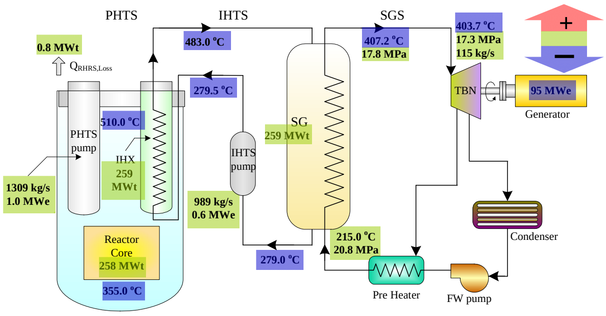

Fig. 4 Heat Balance for 100MWe SFR plant at lowered core temperature condition with low-power operation

3. Conclusion

In this study possibility of operation at lowered core temperature using an identical system is evaluated based on heat balance calculation. A virtual 100MWe prototype reactor is postulated and its operating condition at higher core temperature has been decided by DENOP-K code as a reference condition. Heat balance calculation at lowered core temperature condition has been done and operation strategy was decided by comparing with reference case.

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